Surface properties of polyetheretherketone after different laboratory and chairside polishing protocols

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Abstract: STATEMENT OF PROBLEM Polyetheretherketone (PEEK) can be used as a framework material for fixed dental prostheses. However, information about laboratory and chairside polishing methods is still scarce. PURPOSE The purpose of this in vitro study was to determine the effects of laboratory and chairside polishing methods on the surface roughness (SR) and surface free energy (SFE) of PEEK, an autopolymerizing poly(methyl methacrylate), and a veneering composite resin. MATERIAL AND METHODS For each of the 3 materials, 80 specimens were prepared (N=240) and divided into 7 polishing groups and 1 control group (n=10). The 7 groups were split into 4 laboratory protocols: polishing paste (Abraso), a second polishing paste (Opal L), silicone polisher (Ceragum), and diamond grinder (Diagen-Turbo grinder). The other 3 groups were chairside protocols: rainbow technique (Super-Snap kit), polishing paste (Prisma gloss), and a polishing system (Enhance finishing). Machine polishing with SiC P4000 served as the control treatment. The protocols' average SRs and SFEs were measured, and their surface topographies were evaluated with scanning electron microscopy (SEM). The logarithmically transformed data were analyzed using covariance analysis, 2-way and 1-way ANOVA, and partial correlation (=.05). RESULTS The polishing protocol exerted the highest influence on SR and SFE values (P<.001; SR: partial eta squared P(2)=.970; SFE: P(2)=.450), followed by material group (P<.001, SR: P(2)=.319; SFE: P(2)=.429). The interaction effect of the binary combinations of the 2 independent parameters (polishing protocol and material group) was also significant (P<.001, SR: P(2)=.681; SFE: P(2)=.365). CONCLUSIONS Chairside methods presented lower SR values than laboratory methods, and specimens polished using the 2-body mode showed higher SR than did specimens polished using the 3-body mode.

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ABSTRACT

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Purpose. The purpose of this in vitro study was to determine the effects of laboratory and chairside polishing methods on the surface roughness (SR) and surface free energy (SFE) of PEEK, an autopolymerizing poly(methyl methacrylate), and a veneering composite resin.

Material and methods. For each of the 3 materials, 80 specimens were prepared (N=240) and divided into 7 polishing groups and 1 control group (n=10). The 7 groups were split into 4 laboratory protocols: Abraso (polishing paste), Opal L (polishing paste), Ceragum (silicone polisher), and Diagen-Turbo-Grinder (diamond grinders). The other 3 groups were chairside protocols: Super-Snap rainbow technique kit, Prisma gloss (polishing paste), and Enhance finishing and polishing system. Machine polishing with SiC P4000 served as the control treatment. The protocols' average SRs and SFEs were measured, and their surface topography was evaluated with scanning electron microscopy (SEM). The logarithmically transformed data were analyzed using covariance analysis, 2-way and 1-way ANOVA, and partial correlation (α=.05).

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Conclusions. Chairside methods presented lower SR values than laboratory methods, and specimens polished using the 2-body mode showed higher SR than did specimens polished using the 3-body mode.

CLINICAL IMPLICATIONS

According to the SR and SFE values, polishing pastes (Abraso, Opal L, and Prisma gloss) should be used when polishing PEEK restorations.

INTRODUCTION

Polyetheretherketone (PEEK) is a synthetically produced polymeric material belonging to the polyacryletherketone (PAEK) family. Because of its excellent chemical, thermal, and mechanical properties and its excellent biocompatibility,[1] PEEK is used in various areas of dentistry.[2-4] Since the material possesses a grayish-brown or pearl-white opaque color, a veneering composite resin (COMP) material is also needed for esthetics.[5,6] Relevant parameters for evaluating the clinical longevity of dental restorations include water absorption, polymerization shrinkage, dimension stability, and polishing ability. PEEK has been shown to absorb less water than poly(methyl methacrylate) (PMMA), even after an immersion period of 10 days at 121°C.[7,8] While PMMA and composite resins show a polymerization shrinkage of approximately 2% to 4%, PEEK does

not shrink during the polymerization process and remains chemically inert.[4,9] Furthermore, PEEK offers high stability with regard to hardness, rigidity, and strength, even over a wide range of temperatures; this results in less deformation than other thermoplastic materials.[4]

Obtaining a polished surface is not only crucial for esthetics, it is also a key factor in bacterial plaque accumulation,[10,11] as a direct correlation exists between surface topography and biofilm formation.[12-19] Polishing should result in a final surface roughness (SR) below a threshold value of 0.2 μm in addition to a low surface free energy (SFE); if necessary, this can be accomplished by using different polishing devices.[20] The surface quality depends on several parameters (type of polisher, velocity, contact pressure, surrounding media, and surface quality) and on how much abrasive wear of the dental restorative-material surfaces is intended.[21] Available polishing methods include 2-body abrasion (including grinding burs and both bonded and coated abrasives) and 3-body abrasion (consisting of polishing pastes such as aluminum oxide or diamond particles).[22] The correct material performance and the relationship between the material's hardness and its wear characteristics, light reflectiveness, surface topography, and roughness need to be considered.[23,24]

Dental technicians and dentists are facing the challenge of identifying an adequate polishing method because of the plethora of different methods and lack of precise guidelines. Data on the optimal method of polishing PEEK and its impact on SR and SFE is lacking. Therefore, this study investigated PEEK's polishing characteristics relative to those of PMMA and COMP. The null hypothesis tested was that the polishing protocol would not affect the tested materials' SR or SFE.

MATERIAL AND METHODS

The impact of 7 polishing protocols, with an unpolished group as a control, was investigated. Four laboratory and 3 chairside methods of PEEK processing (bioHPP; bredent GmbH & Co KG) were assessed with regard to SR, SFE, and surface topography. Additionally, PEEK values were compared with those of 2 conventional polymers: autopolymerizing denture PMMA (uni.lign PF 20; bredent GmbH & Co KG) and a veneering composite resin COMP (crea.lign; bredent GmbH & Co KG) (Table 1). To minimize the outcome variability, all preparations, polishing procedures, and evaluations were conducted by the same investigator (S.H.).

The manufacturer provided 80 disks made of PEEK (3 mm high, 15 mm in diameter). Individually fabricated silicone molds with standardized geometries of 15×15×3 mm were used as templates to produce the PMMA (n=80) and COMP (n=80) specimens. PMMA powder (13 g) was mixed with the liquid (9 mL), used to fill the silicone molds, and polymerized in a pressure pot (Palamat Elite; Heraeus Kulzer GmbH) for 20 minutes at 0.45 MPa using warm (55°C) water. To prepare the COMP specimens, the molds were filled with a veneering composite resin layer applied at a thickness of approximately 1 mm per increment. A light-polymerizing unit (bre.Lux Power Unit; bredent GmbH & Co KG) was used to polymerize each layer for 180 seconds at a wavelength between 370 nm and 500 nm. The specimens were ground with silicon carbide abrasive papers (SiC P500; Struers GmbH) for 2 minutes at a contact pressure of 0.3 MPa under constant water cooling. All specimens were prepolished with a fine pumice stone (ERNST HINRICHS Dental GmbH) and goat hair brushes (bredent GmbH & Co KG) for 2 minutes (Table 2).

The 4 laboratory and 3 chairside polishing methods tested are specified in Table 2. To determine SR and SFE, the same specimens (n=10) were used. The surface quality was analyzed

using SR measurements from a contact profilometer (Mahr Perthometer SD 26; Mahr GmbH) and was measured with a diamond-tipped stylus that applied a measuring force of 0.7 mN using 6 readings with a track length of 6 mm. The distance between the lines was set at 0.25 mm. SR was analyzed directly after specimen preparation, after prepolishing with a fine pumice stone (ERNST HINRICHS Dental GmbH), and after final polishing. The accuracy of the profilometer was checked periodically with a calibration block. The profile length was 1.75 mm with a resolution of 0.01 μm. SFE is a measure for quantifying the disruption of intermolecular bonds that occur while a surface is generated. After measuring the contact angles (Kruess Easy Pearl; Kruess GmbH) of the substrate with water (polar) and diiodomethane (dipolar), the SFE (in J/m^2) was calculated using software (DSA4; Kruess) which uses the Owens, Wendt, Rabel, and Kaelble method based on the Young equation and the Fowkes method.[25,26] The measurements were made on every second specimen and at different locations. In all, the SFE was measured on 240 specimens (5 in each group). One specimen of each material and polishing group was selected and gold-sputtered (SC7620 Sputter Coater; Quorum Technologies). The surface topography was evaluated under scanning electron microscopy (SEM) (SUPRA 55VP; Carl Zeiss AG) at 10 kV, with a working distance of 6 mm and using ×15, ×300, and ×600 magnifications.

The assumption of normality was tested using the Kolmogorov-Smirnov test, applied to the residuals of a 2-way ANOVA for SR and SFE. Both primary outcomes (SR and SFE) were logarithmically transformed to stabilize the variance and obtain an approximate normality. A 2-way ANOVA was used to assess, first, the effect of the independent parameters of the polishing protocol and material group and, second, the effect of their interaction on SR and SFE results (the dependent parameter). The significant differences between the materials and polishing protocols were indicated using a 1-way ANOVA followed by a Scheffé post hoc test. A global covariance

analysis was applied to investigate the impact of laboratory-based versus chairside methods and of 2- versus 3-body modes, adjusted for material and polishing protocol. A partial correlation between SR and SFE, adjusted for material and polishing protocol, was computed with software (SPSS v23.0, IBM Corp) (α=.05).

RESULTS

The polishing protocol exerted the highest influence on the SR and SFE values (P<.001, SR: η_P^2=.970; SFE: η_P^2=.450), followed by material group (P<.001, SR: η_P^2=.319; SFE: η_P^2=.429). The interaction effect of the binary combinations of the 2 independent parameters (protocol and material group) was also significant (P<.001, SR: η_P^2=.681; SFE: η_P^2=.365).

For all materials, the protocols affected the SR and SFE values (P<.001 to P=.001) (Table 3). The PEEK specimens that were polished using protocol DIA had higher SR values than the specimens polished using the control or the other protocols, which had SR values in descending order: ABR, OPA, PRI, SUP, CER, and ENH (P<.001). PEEK polished using protocol ENH presented lower SFE than did specimens polished with protocols ABR, DIA, SUP, and PRI or the control (P<.001). The PMMA specimens polished using protocols OPA, PRI, SUP, and the control showed significantly lower SR values than those polished using protocols ABR, CER, and ENH. The highest SR was measured for PMMA specimens polished using protocol DIA (P<.001). With respect to the SFE values, PMMA specimens polished using protocols OPA and ENH showed lower values than those polished using protocol ABR (P=.001). The COMP specimens polished using protocols DIA and ENH showed higher SR than any of the other protocols (P<.001). With respect to the SFE values, the following differences were observed (P<.001): The COMP specimens polished using protocol OPA showed lower values than those

using protocols DIA and ENH, and those polished using protocol CER presented lower values than those using protocol DIA (Table 3).

All protocols were observed to affect the SR values of the material groups (P<.001 to P=.022). For protocol ABR, SR was lowest for PEEK, followed by COMP; PMMA had the highest SR (P<.001). Protocol OPA presented lower SR for PEEK than for PMMA (P=.001). For specimens polished according to protocol CER, the highest SR was for PEEK, followed by PMMA; COMP had the lowest SR (P<.001). Protocol DIA resulted in a higher SR for PEEK than for COMP (P=.011). Within specimens polished using protocols SUP (P<.001) and PRI (P=.022), PEEK presented higher SR values than either PMMA or COMP. Among groups polished using protocol ENH (P=.001) and the control protocol (P<.001), PMMA had higher SR values than either COMP or PEEK (Table 3).

Within groups polished using protocols OPA, PRI, and the control, no impact on SFE values was determined (with P between .061 and .438). The remaining protocols showed an impact of the material group (P<.001 to P=.025). Protocol ABR provided higher SFE for PMMA than for either PEEK or COMP (P<.001). Specimens polished using protocol CER showed higher SFE for PMMA than for PEEK (P=.025). Protocol DIA provided higher SFE for COMP than for either PEEK or PMMA (P=.001). The PEEK specimens polished using protocol SUP had lower SFE values than did either the COMP or the PMMA specimens (P<.001). For specimens polished using protocol ENH, COMP specimens showed higher SFE than did PEEK specimens (P=.001). A global covariance analysis revealed that chairside methods lead to significantly lower SR values (P<.001, η_P^2=.196) than do laboratory-based methods and that specimens polished using the 2-body mode lead to higher SR than do specimens polished using

the 3-body mode ($P<.001$, $\eta_P^2=.720$). By contrast, the type of method had no impact on SFE ($P>.600$).

For laboratory-based methods, protocols DIA and CER caused higher SR values than did protocols ABR and OPA ($P<.001$). With respect to the SFE, polishing using protocols OPA and CER led to lower values than did using protocols ABR and DIA ($P<.001$). In general, the PEEK specimens after polishing showed higher SR than PMMA, and the lowest SR values were observed for COMP material ($P<.001$). In both laboratory-based and chairside methods, PEEK led to lower SFE values than did either COMP or PMMA ($P<.001$). Among the chairside methods, protocols SUP and PRI resulted in lower SR values than did protocol ENH ($P<.001$). Protocol ENH led to lower SFE values than did protocols DIA and SUP ($P<.001$). COMP specimens, after polishing, showed lower SR than did PEEK and PMMA specimens ($P=.001$). No partial correlation was found between SR and SFE after adjusting for material and protocol ($P=.225$). The SEM pictures of all polished surfaces are presented in Figure 2.

DISCUSSION

The null hypothesis of this study was that the examined materials and the different polishing protocols would affect neither SR nor SFE values. For both parameters, the null hypothesis was rejected. In this study, the polishing ability of PEEK specimens compared with those of PMMA and COMP specimens; this was followed by efficiency tests for the 7 different protocols.

To date, no data concerning polishing methods using PEEK restoration material exist, despite this material's potential for restoration due to its outstanding mechanical, thermal, and chemical properties.[1] These considerations justify this study's selection of PEEK for the evaluation of its surface properties and polishing ability. Previous plaque-formation studies have

also found that PEEK can serve as a suitable dental restoration material.[10-12] The initial period of plaque formation – known as the critical or adhesion phase – has a decisive influence on plaque increase, ending in the formation of a manifest incipient carious lesion on neighboring teeth. To counteract this development, it is crucial to guarantee a high-luster, smooth restoration surface with low SR and SFE values to prevent early-settling bacteria from attaching. Even chemical surface properties show crucial impacts on plaque formation.[27]

In previous studies, SR was shown to influence plaque accumulation on titanium implant surfaces. SR values above 0.2 µm led to an increased rate of biofilm formation, whereas SR values less than 0.2 µm had less effect on plaque adhesion.[15,16] Studies have also confirmed increased dental plaque formation on rough surfaces.[17-19] Furthermore, Buergers et al, regarding the correlation between surface properties and the adhesion of *Streptococcus mutans*, concluded that there were correlations both between bacterial adhesion and SFE values and between SFE and SR values; otherwise, however, they found no correlation between SR and fluorescent bacterial biofilm.[14] Thus, whether SR values or SFE values are the more essential factors in evaluating a polishing protocol for bacterial adhesion is unclear.

Further clinical studies are needed to test PEEK in terms of its surface properties and bacterial formation. Particularly within the first 20 hours, PEEK shows a significantly lower formation of viable biomass than do other abutment materials (zirconia and titanium). This may be because even glazed ceramics do not reach SR values below 0.3 µm.[28] In a study by Hahnel et al,[12] PEEK was polished using an automated polishing machine with SiC P4000 grinding paper, comparable to the method used in the control group of the present study. Concerning the impact of the protocol on PEEK, the control group and protocols ABR, OPA, SUP, and PRI showed a lower SR than the other groups did. Protocol ENH achieved the lowest SFE values, and these

differences were significant, but this protocol's SR values were still above 0.2 µm. A key issue in the present study is the distinction between laboratory-based and chairside protocols. Dental restorations should display a smooth surface before being inserted in the oral cavity. In restorations where occlusal adjustment is required, the restoration surface must be adequately repolished. Therefore, both the 2-body and the 3-body modes are available.[22] The 2-body mode includes abrading burs and coated abrasives (comparable to those used in laboratory-based protocols CER and DIA and chairside protocols SUP and ENH). Laboratory-based protocols ABR and OPA and chairside protocol PRI represent 3-body wear using high-gloss polishing pastes. The benefit of using polishing pastes is that the combination of the paste with water leads to a fine abrasive action and a high-gloss, light-reflective surface.[21]

In contrast, the dry version acts in a more aggressive way, causing a higher amount of wear and potentially producing deep notches. The drawback of polishing with pastes is the need to use polishing brushes. Concerning laboratory-based protocols, methods ABR and OPA showed lower SR values than the other methods for all materials. Polishing OPA and CER resulted in lower SFE values than did the other laboratory-based protocols. Among chairside protocols, groups SUP and PRI showed lower SR values across all materials; however, the lowest SFE values were found in group ENH. The Enhance polishing system in protocol ENH led to high SR values (>0.5 µm) across all material groups. These results are comparable to those seen in the PEEK material group. This outcome could be confirmed by testing polishing methods (measure by SR) using different types of composite resins.[29]

In the current study, PEEK showed tangentially lower SFE but higher SR than did either COMP or PMMA. A correlation between the SR and SFE values could not be found, which is conspicuous in that the 3-body wear methods (in particular) reached the best results with regard

to low SR and SFE values for all protocols except the chairside protocol SUP. Potentially decisive aspects that cannot be disregarded include surface properties like hardness, filler degree, and the matrix texture of the polished materials. PEEK shows a hardness of about 110 Vickers hardness number (VHN), which is comparable to that of established PMMA materials. COMP is a considerably harder material, with a hardness value of about 600 VHN.[1] Filler loading could be proven to determine the mechanical properties of composites, depending on their filler morphologies. In this context, a straight proportionality between filler loading and hardness can be assumed.[23,24] The current examinations seem to show that COMP achieved the lowest SR for all the protocols. However, the PEEK specimens achieved lower SR than did either the PMMA or COMP specimens. The assumption is that materials with a high hardness can reach lower SR after polishing than can smoother materials, which end up with lower SFE. Future studies should investigate this correlative thesis.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were made:

1. For the laboratory-based protocols, polishing pastes (protocols ABR and OPA) created PEEK surfaces with lower SR than those produced by protocols CER and DIA. The lowest SFE were achieved using protocols OPA and CER.

2. For the chairside protocols, both protocol SUP and protocol PRI led to PEEK surfaces with lower SR than were produced with protocol ENH. The lowest SFE were achieved in the protocol ENH.

3. Chairside polishing methods resulted in lower SR than did laboratory-based methods.

4. Specimens polished using 2-body mode showed higher SR than did specimens polished using 3-body mode.

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FIGURES

Figure 1. Study design divided into different steps of preparation, prepolishing, clinical polishing, and SR/SFE measurements.

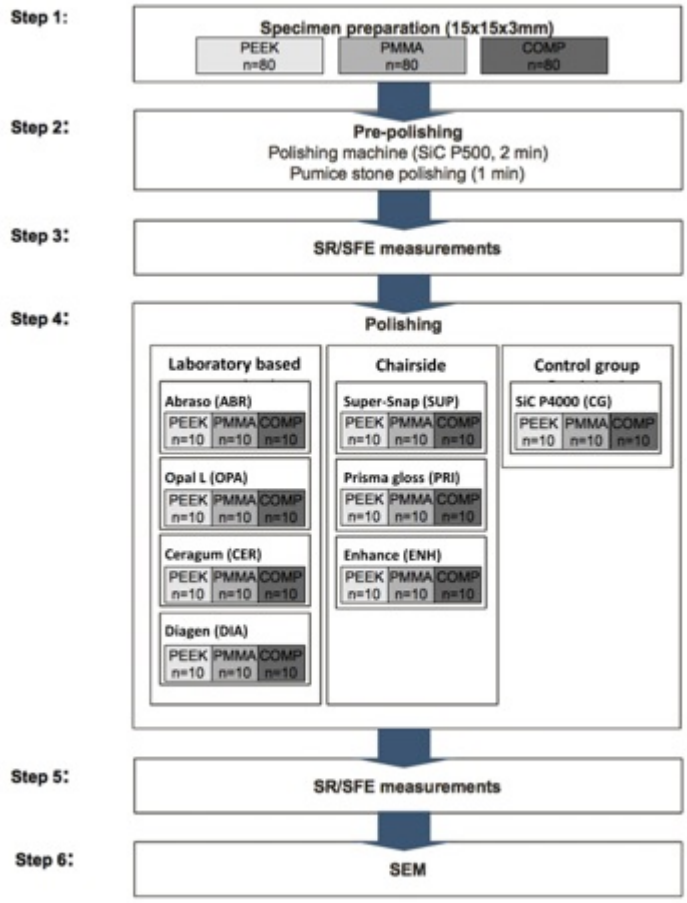
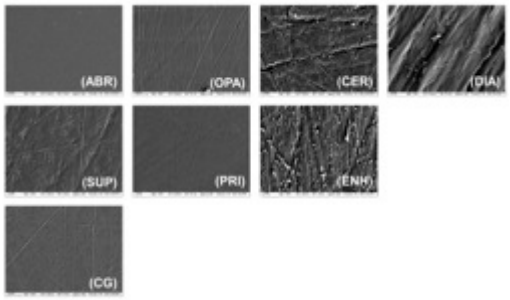


Figure 2. Representative scanning electron micrographs of materials evaluated divided into different polishing protocols (I-VII, CG) (original magnification ×600). A, PEEK. B, PMMA. C, COMP.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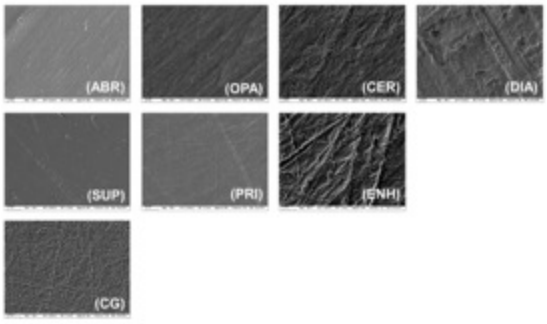
A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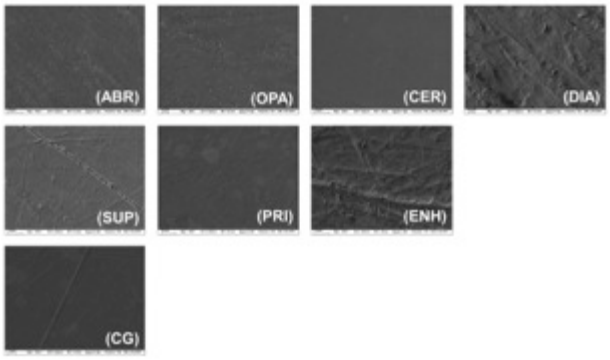
B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C

TABLES

Table 1. Manufacturer`s names, manufacturer, composition properties and lot numbers of test materials

Name	Material	Manufacturer	Lot No.	Composition	Method of Polymerization
PEEK	bioHPP	bredent GmbH & Co KG	410240	ceramic filled (20%) PEEK	press mode
PMMA	uni.lign PF 20	bredent GmbH & Co KG	396617 401822	99% PMMA polymer	pressure pot (Heraeus Kulzer GmbH) (20 min, 55°C, 0.45 MPa)
COMP	crea.lign Incisal E2	bredent GmbH & Co KG	N141331 123765	bis-GMA composite with microfillers	visible light bre.Lux Power Unit (bredent GmbH & Co KG)

Table 2**.** Polishing protocols, products, and manufacturers of polishing burs and finishing-polishing systems used

Polishing protocol		Polishing method
ABR	Abraso polishing paste (bredent GmbH & Co KG)	polishing motor (Kavo Dental GmbH) polishing mobs (bredent GmbH & Co.KG) Duration: 1 min, 3000 U/min
OPA	Opal L polishing paste (Renfert GmbH)	hand piece (KaVo Dental GmbH) polishing mobs (bredent GmbH & Co.KG) Duration: 1 min, 10000 U/min
CER	Ceragum Silicone polisher (bredent GmbH & Co KG)	hand piece (Kavo Dental GmbH) Duration: 1 min, 12000 U/min
DIA	Diagen-Turbo- Grinder (bredent GmbH & Co KG)	hand piece (KaVo Dental GmbH) Duration: 1 min, 12000 U/min
SUP	Super-snap polishing discs (Shofu Dental GmbH)	angle piece (KaVo Dental GmbH) Duration: violet (30 s), green (30s) Pink (30 s), 11000 U/min
PRI	Prisma-gloss polishing paste (Dentsply De Trey GmbH)	angle piece (KaVo Dental GmbH) Duration: dry (40 s), wet (20 s), 8000 U/min
ENH	Enhance polishing system (Dentsply De Trey GmbH)	angle piece (KaVo Dental GmbH) Duration: dry (1 min), 5000 U/min
CG	polishing machine (Struers GmbH)	polishing protocol for each material group PEEK: P1200 (0.3 MPa, 1 min), P4000 (0.3 Mpa, 4 min), P4000 (0.5 Mpa, 4 min) PMMA: P2000 (0.3 MPa, 2 min), P4000 (0.3 MPa, 2 min) COMP: P500 (0.5 MPa, 4 min), P1200 (0.5 Mpa, 4 min), P2000 (0.5 MPa, 6 min), P4000 (0.5 Mpa, 8 min)

Table 3. Overview of mean values, standard deviations, and 95% confidence intervals after clinical polishing and SR/SFE measurements divided into different materials (PEEK, PMMA, COMP). Average SR values are listed in µm, mean SFE values are measured in J/m^2

	Polishing protocol	SR Mean ±SD	SR (95% CI)	SFE Mean ± SD	SFE (95% CI)
PEEK					
laboratory-based	ABR	0.034 ±0.010^{aA}	(0.025;0.042)	44.9 ±2.0^{bA}	(42.3;47.5)
	OPA	0.046 ±0.008^{aA}	(0.039;0.052)	39.9 ±4.0^{abA}	(34.8;44.9)
	CER	0.424 ±0.117^{dC}	(0.339;0.508)	39.0 ±3.4^{abA}	(34.7;43.3)
	DIA	1.337 ±0.265^{eB}	(1.146;1.528)	45.4 ±1.0^{bA}	(44.0;46.7)
chairside	SUP	0.118 ±0.027^{cB}	(0.097;0.137)	43.6 ±2.1^{bA}	(40.8;46.2)
	PRI	0.072 ±0.009^{bB}	(0.025;0.042)	46.7 ±5.3^{bA}	(39.9;53.3)
	ENH	0.5670 ±0.103^{dA}	(0.495;0.644)	34.3 ±4.1^{aA}	(29.1;39.4)
CG	CG	0.032 ±0.003^{aA}	(0.028;0.035)	45.9 ±1.8^{bA}	(43.5;48.1)
PMMA					
laboratory-based	ABR	0.103 ±0.021^{bC}	(0.087;0.119)	56.5 ±2.9^{bB}	(52.8;60.1)
	OPA	0.064 ±0.012^{aB}	(0.054;0.074)	43.0 ±7.3^{aA}	(33.8;52.1)
	CER	0.268 ± 0.055^{cB}	(0.227;0.308)	45.4 ±4.7^{abA}	(39.4;51.3)
	DIA	1.127 ±0.273^{eAB}	(0.930;1.323)	47.2 ±2.2^{abA}	(44.3;50.0)
chairside	SUP	0.063 ±0.015^{aA}	(0.051;0.074)	52.2 ±3.4^{abB}	(47.9;56.4)
	PRI	0.062 ±0.007^{aA}	(0.056;0.068)	48.6 ±2.3^{abA}	(45.6;51.6)
	ENH	0.684 ±0.078^{dB}	(0.627;0.741)	42.9 ±6.5^{aA}	(34.6;51.0)
CG	CG	0.072 ±0.004^{aB}	(0.067;0.076)	48.5 ±2.3^{abA}	(45.4;51.4)
COMP					
laboratory-based	ABR	0.059 ±0.017^{bB}	(0.045;0.071)	47.9 ±3.1^{abcA}	(43.9;51.7)
	OPA	0.055 ±0.011^{abAB}	(0.046;0.063)	43.9 ±2.0^{aA}	(41.3;46.4)
	CER	0.099 ±0.041^{cA}	(0.068;0.128)	45.0 ±2.6^{abA}	(41.6;48.3)
	DIA	0.989 ±0.097^{eA}	(0.918;1.059)	52.9 ±3.7^{cB}	(48.2;57.5)
chairside	SUP	0.074 ±0.018^{bcA}	(0.060;0.088)	49.5 ±1.8^{abcB}	(47.2;51.7)
	PRI	0.062 ±0.008^{bcA}	(0.055;0.069)	50.2 ±2.7^{abcA}	(46.8;53.6)
	ENH	0.517 ±0.067^{dA}	(0.468;0.566)	51.8 ±4.0^{bcB}	(46.7;56.7)
CG	CG	0.038 ±0.014^{aA}	(0.027;0.048)	48.8 ±1.6^{abcA}	(46.6;50.9)

^{abcd} Different superscript lowercase letters represent significant differences between polishing protocols within one material group.
^{ABC} Different superscript uppercase letters represent significant differences between materials within one polishing protocol.